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Little Leaf Disease of Pine

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INTRODUCTION AND SUMMARY

In 1934 and 1935, reports were received of an unexplained dying of shortleaf pine (*Pinus echinata* Mill.) in parts of Alabama. Examination within the next few years indicated that a general rapid decline of shortleaf pine, and to a lesser extent of loblolly pine (*P. taeda* L.), was taking place over wide areas. This decline was characterized by marked reduction in twig and trunk-diameter growth and by shortened and yellowish foliage. Many trees that had made good growth for 20 years or more went through a period of marked reduction in growth for 3 to 15 years, during which they exhibited poor foliage and dying of twigs. Many affected trees have died. This decline has become known as the little leaf disease of pine.

The disease occurs in the Piedmont region from central Virginia to Alabama, in the northern half of Alabama, the northeastern tip of Mississippi, and a few counties of eastern Tennessee.

Siggers and Doak,[3] who made the early investigations of little leaf, recognized it as a distinct malady, apart from the ordinary effects of

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[1] Investigated distribution, symptoms, and disease progress. Results to be published in detail later have been presented in partial fulfillment of the requirements for the degree of doctor of philosophy, Yale University.

[2] In cooperation with the University of Georgia, Alabama Polytechnic Institute, and the Appalachian Forest Experiment Station of the U. S. Forest Service. The authors wish to acknowledge the assistance of E. Richard Toole and E. R. Roth, both of the Division of Forest Pathology, and many cooperating private and public agencies.

[3] SIGGERS, P. V., and DOAK, K. D. THE LITTLE-LEAF DISEASE OF SHORTLEAF PINES. U. S. Forest Serv., South. Forest Expt. Sta. Occas. Paper 95, 5 pp., illus. 1940. [Processed.]

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fire, bark beetles, known pine diseases, or generally recognized unfavorable site factors. The cause of the disease has not been determined. Theories regarding the cause have been divergent, including the possibilities of weather, insects, virus, unfavorable soil conditions, and root fungi, and deficiencies of soil nutrients, minor elements, or soil water.

In 1939 an extensive program of research was begun, directed largely toward determining the cause of the disease and working out its symptoms, distribution, progress, and effects. With the cause possibly lying somewhere in the province of soils, pathology, entomology, or plant physiology, it has been necessary to make exploratory investigations over a wide field for the first few years, so as to miss no ready answer to the problem. Some theories were eliminated, and intensive studies have now been directed toward the remaining most probable approaches to the cause. Of the volume of information accumulated on the behavior of shortleaf pine, the part that bears on little leaf is discussed in this circular. The relation of little leaf to soil and site factors and the role of the disease as it affects timberland management are emphasized.

From present indications little leaf appears not to be caused by weather, by lack of phosphorus or potash, nor by lack of soil moisture. Experiments indicate that among the possible causes the following remain prominent: Lack of some element, as nitrogen or boron; improper physical condition of the upper soil layers; two root fungi; and perhaps a virus. Other possibilities still remain, and further conclusions must await the results of comprehensive experiments now under way.

Trees less than 20 years of age rarely show little leaf. Heavy losses generally develop between the ages of 30 and 50 years. Trees in the earliest recognizable stages of the disease will live an average of only 7 years, those in the middle stages 4½ years, and those in the advanced stages 2½ years.

A time of critical shortage in pine pulpwood provides an unusual opportunity for the profitable disposal of little leaf timber, and operators are urged to salvage as much of this timber as possible for whatever purpose its size may be suitable. The suggested cutting practice consists of making the first cut soon after the disease appears. Where feasible, succeeding cuts should be made at least every 5 years, and all trees showing symptoms removed. The number taken out during each cut will depend upon the severity of the disease and of any accompanying bark beetle attacks. This practice will often result in a complete cut of the original stand at the end of 50 years or soon after.

SPECIES AFFECTED

Little leaf affects primarily shortleaf pine. In some sections, surveys [4] and examinations of permanent plots have shown loblolly pine and occasionally Virginia pine (*Pinus virginiana* Mill.) and pitch pine (*P. rigida* Mill.) also to be affected. Similar symptoms occur on longleaf pine (*P. palustris* Mill.) in a few places. Longleaf pine in mixture with diseased shortleaf rarely shows symptoms, and the cases of affected longleaf seen have largely been south of the so-called little leaf belt. It is possible that the cases of degenerated longleaf, while appearing similar to little leaf disease, actually represent a different condition. No other pine is known to be affected by the disease.

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[4] BOGGESS, W. R., SWARTHOUT, P. A., and TOOLE, E. R. RESULTS OF THE SURVEY ON THE LITTLE-LEAF DISEASE OF SOUTHERN PINES IN ALABAMA. Ala. Agr. Expt. Sta. 15 pp., illus. 1941. [Processed.]

DISTRIBUTION OF THE DISEASE

The known distribution of little leaf is shown in figure 1 in its different degrees of severity. This map has been compiled over a period of 5 years from observations made by members of the Division of Forest Pathology and from their confirmation of observations made by many agencies and individuals. In at least 38 of the 109 counties in which the disease is known it is causing damage to such an extent that it must be considered in forest-management plans.

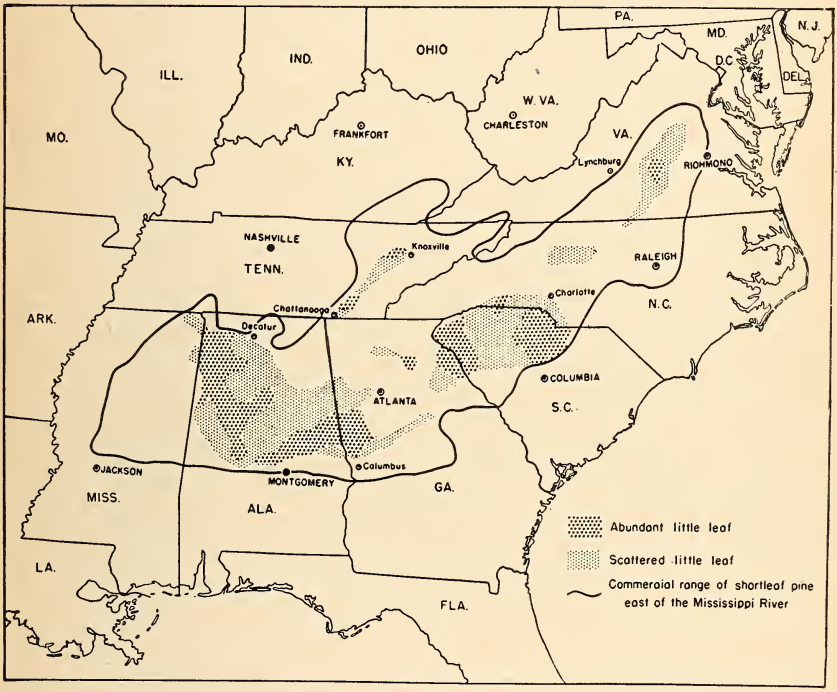

FIGURE 1.—Known distribution of the little leaf disease of shortleaf pine.

Shortly after the first reports of little leaf from Alabama were verified, diseased trees were found in abundance in west-central Georgia. Extensive scouting during the next few years showed it to occur in varying degrees through much of the Piedmont of the Southeastern States and in the northern half of Alabama, just within the northeastern corner of Mississippi, and in a few counties in Tennessee. The commercial range of shortleaf pine extends far beyond the limits of the little leaf belt, particularly westward, but so far the disease has not been found in the shortleaf pinelands of Louisiana, Texas, Arkansas, Oklahoma, or Missouri, and very little has been found in the extensive shortleaf pine areas of eastern Mississippi, central Georgia, and central North Carolina.

The question of whether little leaf is spreading cannot yet be answered. Affected areas not previously found are still being discovered, but in most cases, judging from the appearance of the trees, these areas seem merely to have been overlooked previously or unreported. In some instances, however, actual extension of the disease into new areas appears to have occurred, and precise records on spread are now being kept for several localities. The disease has become much worse during the last 5 years in most of its localities.

ECONOMIC IMPORTANCE

Shortleaf pine is one of the most abundant and important of the southern pines and is a major commercial species in at least 13 States. It is the predominant softwood in the Piedmont region, which lies between the mountains and the coastal plain of the Southeastern States. There are approximately 11,000,000,000 board feet of shortleaf pine on 41,000,000 acres within the area in which little leaf occurs and several billion feet more to the west. Loblolly pine, which appears to be affected by little leaf only when associated with diseased shortleaf, also occurs over much of the range of the shortleaf pine.

It is difficult to arrive at a reliable estimate of the quantity of timber that has died of little leaf, but it would easily amount to several million board feet. For example, on two of the many national forest units within the little leaf belt, approximately 3,000,000 board feet of shortleaf pine is now affected with the disease, and salvage methods are being employed to harvest much of this timber before it dies. Small trees are being cut for pulpwood over wide areas of the Piedmont, because the appearance of little leaf marks them for early death. While this has swelled the much-needed wartime production of pulpwood, this heavier cutting, together with the large acreage of unharvested pine that is dying of the disease in certain areas, will result in much less shortleaf pine and more hardwoods in the future.

Data from 14 severely diseased study plots showed an average annual death of 5.4 percent of the leading trees in the stands (the dominants and codominants) and at least equal losses among the trees of lesser dominance. Annual losses among the dominants and codominants alone on 6 of the 14 plots ran as high as 11 to 21 percent of the trees in a single year.

In addition to killing trees, little leaf greatly reduces the growth rate. It is common to find trees that had been growing as much as half an inch in diameter a year drop to a few hundredths of an inch each year for several years prior to death. Thus, millions of trees in the forests of the little leaf belt that are occupying growing space are almost at a standstill in growth.

In some sections little leaf is causing a gradual decline in cutting for lumber and an increase in the cutting of this species for small products—small poles, pulpwood, cross ties, and fuel. In time the disease may make a shift in some industries necessary if full advantage is to be taken of the increased ratio of shortleaf pine pulpwood over saw timber.

SYMPTOMS

Trees affected by little leaf have a sickly appearance (fig. 2). Symptoms may appear suddenly, but usually a tree gradually appears weaker, as less growth is put on each year until premature death. In general, all major organs of these diseased trees show the effects of a decline in vigor, and the picture that the trees present is what one would expect from starvation for nutrients. Little leaf may develop at any time after trees are about 20 years old, and then within a few years extreme symptoms appear and the trees die. The best trees, the dominants and codominants, are killed as readily as any others in the stand. Healthy-appearing shortleaf pines occur commonly side by side with severely diseased trees, their roots occupying practically the same ground. Plot records, however, show that many of these interspersed normal-looking trees eventually develop little leaf. Severe disease losses are taking place on many soils that appear capable of supporting vigorous shortleaf pine growth. Detailed examination of 70 trees, supplemented by periodic observations on several thousand shortleaf pines on 35 permanent plots, have shown the symptoms to be as follows:

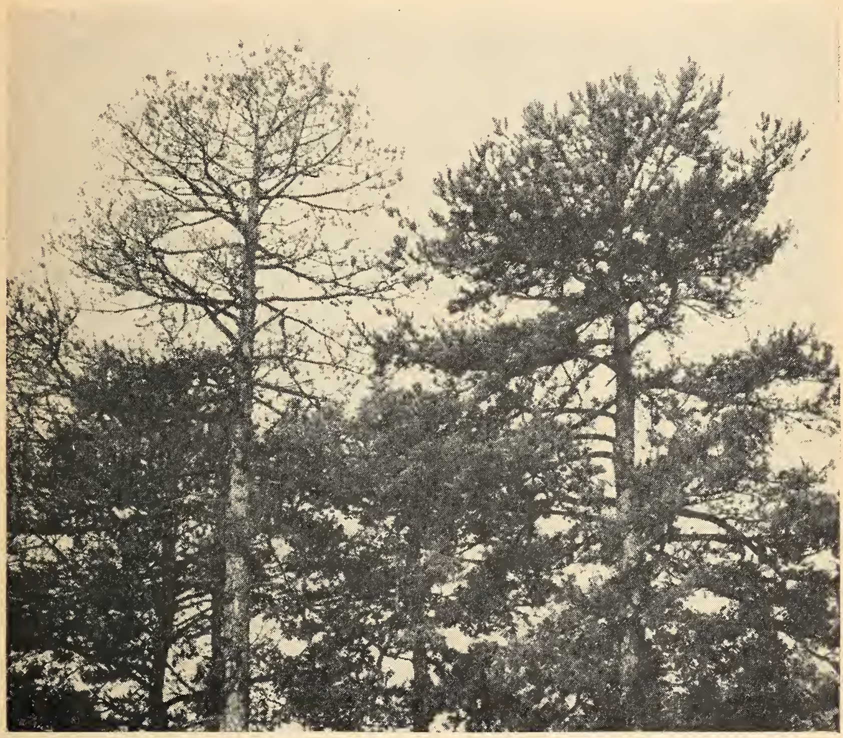

Figure 2.—Left, a shortleaf pine in the advanced stage of the little leaf disease; right, a healthy shortleaf pine of the same age.

Shorter needles are produced as the disease progresses, although they are usually retained for the normal two to three growing seasons.

Foliage is often yellowish in severe cases, but the color is variable and sometimes is normal green. Moisture content and anatomic structure of needles are normal. Analyses [5] of foliage ash by the spectrographic method have indicated that, as compared with needles from healthy trees, diseased needles are low in calcium, manganese, copper, and aluminum; normal in magnesium, iron, potassium, and phosphorus; and high in boron. Chlorides, determined by the chemical method, also appeared relatively high in diseased foliage.

The most striking symptom of the disease is the sparse foliage resulting from progressive annual shortening of twig growth (fig. 3). Diseased trees produce only one internode a season, whereas healthy trees often produce two or more. As the disease progresses, twigs and branches die throughout the crown, starting in the lower part, and sprouts commonly develop on the branches.

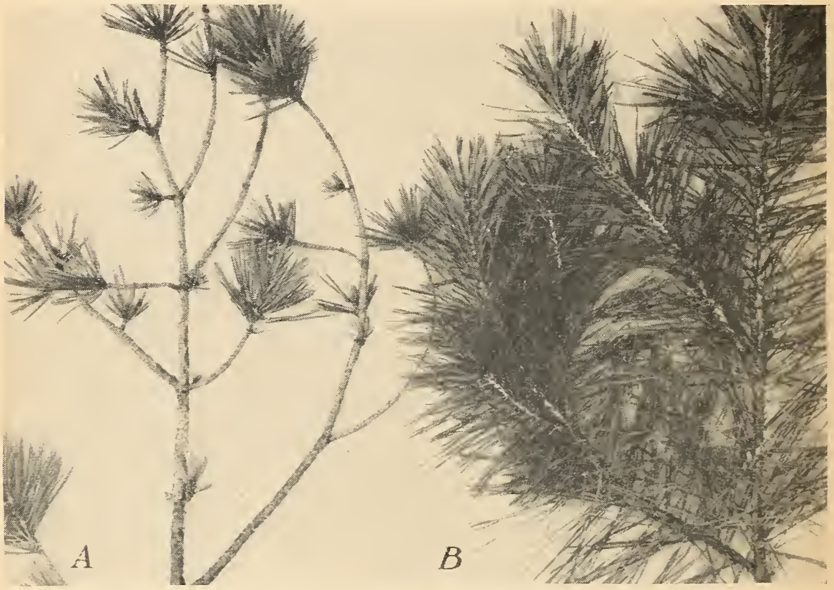

FIGURE 3.—A branch bearing 2 years' growth of needles from (*A*) a typically diseased shortleaf pine and one from (*B*) a healthy shortleaf pine.

Height and trunk-diameter growth gradually decline, although abrupt decline often occurs in diameter growth to the point where the annual rings can hardly be counted (fig. 4). Moisture content of the wood is normal at all heights. No significant structural or anatomical abnormalities occur.

Cones are abnormally small, with fewer, smaller, and less viable seeds. Diseased trees usually retain their cones longer than healthy trees.

The roots of little leaf and normal trees were studied by washing away the soil with a pressure hose. The form, extent, and distribution of the roots of diseased trees are normal. The shortleaf pine has a well-developed taproot, a lateral root system that may extend as much as 30 to 40 feet radially, and a system of fine feeding roots distributed in the upper 3 inches of the soil. The surface of roots of little leaf trees is dull and scaly, and a high proportion of the feeding roots are dead at the ends. The root symptoms are treated in greater detail under the discussion of Fungi, on page 11.

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[5] The foliage analyses were made by B. C. Brunstetter and A. T. Myers, of the Division of Fruit and Vegetable Crops and Diseases, of this Bureau.

INVESTIGATIONS ON THE CAUSE

Since little leaf is a systemic disturbance—that is, the entire tree is affected—the possibilities of weather, soil, and water factors, root disease, insects, or a virus predominate in the hypotheses as to the cause. Attention has been given these possibilities and some others as well, and experiments already set up should go a long way toward disposing of many of them after enough time has elapsed for the full effects of the experiments to develop.

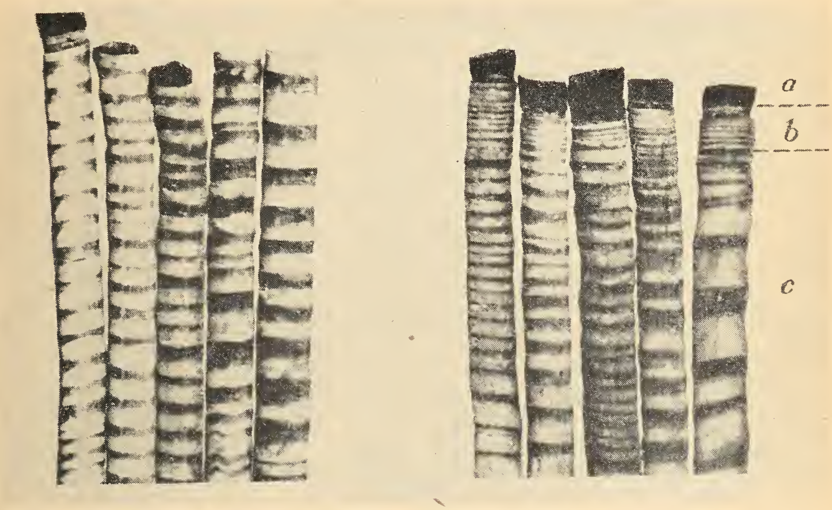

Figure 4.—Left, increment cores from healthy dominant shortleaf pines. Right, cores from dominant trees affected by little leaf: *a*, Bark; *b*, wood, showing reduced growth rings during recent years; *c*, wood, showing normal growth rings during earlier years. × 1⅓.

Weather

Reports of low water tables in parts of the little leaf belt, recent droughts, and an apparent dryness of the wood of diseased trees reported by some wood cutters led to a comparison of the quantity of rainfall for vicinities where little leaf was severe and corresponding localities in the Piedmont region where the shortleaf pine was normal. These analyses were made on the basis of departure from normal precipitation for each year in the period 1921 through 1938 and for each quarter of each year. When rainfall was high or low for the little leaf localities, it was almost always correspondingly high or low for the healthy localities. There was no particular season of the year when rainfall was high for the one group of localities but low for the other; the rainfall trends were very similar. At the end of the period 1921–38, the average rainfall for three towns near little leaf areas had shown neither an accumulation nor a deficiency, while the average for three towns near healthy shortleaf pine stands had a deficiency of a little more than 6 inches for the 18-year period—a negligible quantity.

The unlikelihood of a correlation of rainfall deficiency with little leaf is emphasized by a comparison of conditions at Greenville, S. C., where there was an abundance of healthy shortleaf nearby and an accumulated deficiency of 92 inches of rainfall from 1921–38, with conditions at Santuck, S. C., where there was abundant diseased shortleaf nearby and an accumulation of 6 inches of rainfall above normal during this period.

Similar studies were made on temperature. While records show that the Southeast as a whole has had rather consistently above-normal temperatures since the early 1920's, the difference between temperature in the towns near diseased and near healthy shortleaf pines was very small, with departure from normal temperature higher for the healthy than for the little leaf localities.

SOIL AND SITE [6]

The quantity of precipitation that reaches the roots is influenced to a large extent by the physical state of the soil. Periodic measurements of soil moisture by the porous-block electrical-conductivity method were made within the soil area of the root system of both healthy and badly diseased trees on sandy loams of three different soil series in Alabama. Measurements were made at three depths. This experiment, run for almost a year, showed that the soil moisture fluctuated in a manner similar to the rainfall, under both healthy and diseased trees. Pore space was also comparable at different depths for two soils under both healthy and diseased trees.

The intensity of the disease varies with environmental factors, but none of these relations is strongly indicative of the cause. Typical little leaf has not been found in the mountains proper or in the sandy soils of the lower Coastal Plain, but it does occur severely on some mountain soils along the edges of the Appalachian Range, and it has been found on some sands in central Alabama. The soils under diseased stands generally have thinner topsoil and a higher clay fraction than soils under healthy stands, and they are more eroded and poorer, as judged by the performance of agricultural crops. On the other hand, severe little leaf has been found on good soils, in moist sites, and in shortleaf pine stands that grew more than 80 feet in 50 years—a very high site index for this species.

Little leaf tends to be more severe on burned-over areas, but it can often be found in areas unburned for more than a decade. Stand composition seems to bear little relation to little leaf, since severe disease occurs in areas of pure shortleaf, in the presence of other intermixed southern pines, and with a hardwood mixture of 50 percent of the overstory trees.

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[6] Much of this section is from E. Richard Toole's unpublished manuscript entitled "Soils and Little Leaf," dated August 1942.

Neither density of stocking nor forest type appears to bear a close relation to the disease. Little leaf is generally more severe on steep or dry slopes and where fire, erosion, and land misuse have decreased soil productivity, but it is not confined to such situations.[7] It is to be expected that the symptoms of this disease will be accentuated under adverse growth conditions.

Little leaf has been found on more than 25 soil series and on soils of texture varying from sand to clay. A large number of chemical analyses were made from soils supporting diseased and healthy stands in many localities. With standard methods tests were made for exchangeable calcium, available phosphorus, total phosphorus, exchangeable potassium, total nitrogen, and organic carbon. These tests were made for healthy and for diseased stands within a given soil series and type for four soil series. There were tendencies toward slightly higher exchangeable calcium and potassium, higher organic carbon, and lower available phosphorus in soils supporting healthy stands, but none of the differences were consistent enough to have mathematical significance.

No beneficial effects resulted from the injection of solutions of zinc sulfate, sodium borate, magnesium sulfate, manganese sulfate, or copper sulfate into shoots of diseased trees. Similarly, no beneficial effects resulted from trunk injections of dry sulfur, borax, or zinc sulfate.

In 1941 one-tenth-acre plots near Dadeville, Ala., each containing several little leaf trees, were treated with fertilizers broadcast over the surface of the ground on and around the plots. Each treatment was used on two plots, and the plots have been examined six times since their establishment, the last examination being in October 1944. The treatments used and the progress of the disease under each treatment for only the dominant and codominant trees are given in table 1.

TABLE 1.—*Progress to 1944 of little leaf disease near Dadeville, Ala., after treatment of pineland with amendments, beginning in 1941*

Treatment	Trees healthy in 1941		Trees diseased in 1941	
	Total	Showing evidence of disease by 1944	Total	Becoming worse or dying by 1944
Nonnitrogen plots:	*Number*	*Number*	*Number*	*Number*
Check (no treatment)	32	14	24	20
Forest litter added	15	8	12	11
Forest litter raked off	2	1	9	9
Phosphate (P)	30	21	15	12
Phosphate+potash (PK)	11	6	9	7
Total	90	50	69	59
Nitrogen plots:				
Nitrogen+P+K (NPK)	15	0	9	3
NPK+zinc sulfate	9	1	9	7
NPK+sodium borate	5	2	12	1
NPK+five trace elements	14	3	14	2
Total	43	6	44	13

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[7] See footnote 4, p. 2.

In the treatments given above, all plots were refertilized at the end of 2 years and all plots with nitrogen were given a supplemental nitrogenous dressing at the end of 1 year. The quantities of the carriers of major nutrients and trace elements were as follows:

	Pounds per acre
Major nutrients:	
P as superphosphate (16-percent P)	1,000
K as muriate of potash (50-percent K)	160
N as sodium nitrate (16-percent N)	200
N as ammonium sulfate (20-percent N)	200
Trace elements:	
Zinc sulfate	25
Sodium borate	15
Magnesium sulfate	50
Manganese sulfate	50
Copper sulfate	25

The results of the fertilizer treatments indicate benefit from the addition of nitrogen. When the treatments included nitrogen fewer trees developed little leaf, and in all nitrogen treatments, excepting the one including zinc, the decline of the diseased trees was checked. Nitrogen promoted better needle color, longer needles, and improved shoot growth of diseased trees, and this benefit was greatest where borax (sodium borate) also was added. Several diseased trees fertilized with NPK+borax appear almost completely recovered. In a new experiment high rates of application of sodium nitrate alone, ranging up to 1,600 pounds per acre, made in June, caused the foliage of little leaf trees to improve in color by September. In these tests borax alone had either no effect or was toxic, depending upon the rate of application.

Since the experiment just described consisted largely of surface additions of inorganic fertilizers, further experiments have recently been set up in which the soil amendments include stable manure, prepared compost, and applications of hardwood leafmold, as well as inorganic fertilizers containing nitrate, with and without borax, and borax alone. In half the treatments the added material was spread on the surface, and in the other half it was worked in to a depth of 4 to 6 inches. Insufficient time has elapsed to evaluate the results of these experiments.

Foliage sprays of the following compounds have also been applied three times: Sodium borate, manganous sulfate, ferrous sulfate, magnesium sulfate, copper sulfate, zinc sulfate, nickelous sulfate, cobaltous acetate, and ammonium molybdate. At the end of 1 year no noticeable benefit had resulted.

The results of the soil treatments are suggestive but not conclusive. The benefits from nitrogen applications may indicate insufficient available nitrogen in the soil for normal shortleaf pine development, but in view of the low nitrogen requirement of this species and the relative suddenness of the onset of little leaf, it more likely indicates a deterioration of the root system that reduces the uptake of nitrogen to a critical level.

Carbohydrate Relations

Precise quantitative analyses have been made of food reserves, largely starches and sugars, in the bark and wood of normal shortleaf pines and of trees with little leaf symptoms. For roots and trunks these analyses were made each month throughout the course of 1 year, and for foliage at one period in spring. The root bark was found to be the most efficient food-storage area in the tree; it also provides most of the food for root growth. Therefore, it is significant that the root bark of little leaf trees had an average of less than half as much food as that of healthy trees through the year and that at times reserve food was almost entirely absent from the bark of some roots of diseased trees. On the other hand, stem bark of diseased trees had a food content generally equal to that of normal trees. The foliage of diseased trees was low in reserve food. The analyses indicated that a typical little leaf tree may be producing only 10 percent of normal food and that the roots suffer particularly from this deficiency, with dieback and early formation of scaly bark (brown patch) resulting.

Mechanical Interference

Since the symptoms of little leaf are such that loss of roots or interference with conduction could conceivably be involved in the cause, several methods of injuring healthy trees have been tried to see if the disease could be induced. Most of these experiments have run through only three growing seasons, so that their full effect cannot yet be evaluated. The crowns of some of the trees, however, already show symptoms not unlike little leaf. The following treatments, arranged in descending order of effectiveness, have been used: 60 percent of lateral roots severed; trench made at a radius of 4 to 10 feet, cutting the roots; primary roots exposed; overlapping partial girdles made; spiral girdle cut deep into the wood; ordinary deep girdle made three-fourths of the way around; spiral girdle made just through bark; three-fourths girdle made just through bark; and taproot severed. Interference with the lateral root system has generally resulted in the most pronounced decline of the crowns and at the same time has shown the closest resemblance to typical little leaf symptoms.

Fungi

Examination of the aerial parts of diseased trees has failed to show any external or internal infections that appeared related to the disease, and culture studies and microscopic examinations have yielded no evidence of disease-causing fungi or bacteria in the bark or wood. It seems, therefore, that the disease is not the result of this type of infection in the above-ground parts of the trees.

The roots have been given particularly close attention because of the possibility that the disease results from some condition either of the roots or of the soil. The roots of little leaf trees are almost always in a deteriorated condition. The principal symptoms are heavy loss of feeding roots, resulting largely from dieback; extensive incrustation of roots with areas of dead bark, called brown patch; and deep elongate lesions in the bark and wood, called pitch cankers. Brown patch, which is a term for areas of scaly bark, occurs normally on fairly large roots of all southern pines; but on little leaf trees it forms early on small roots, probably owing to their deficiency in reserve foods, and gives these roots a rough, scaly appearance, as compared with the smooth, reddish surface of the small roots of normal trees. A fungus of the genus *Torula* is intimately associated with brown patch formation and can be isolated readily from patches just forming on diseased or healthy trees of any of the several species of southern pine under consideration.

During root excavations, fungus masses (sclerotia) of *Poria cocos* Wolf, known as tuckahoe, or Indian bread, were frequently found on the roots of diseased trees, but not on healthy ones. This fungus, however, has never been isolated directly from any of such root defects as dead root ends, brown patch, or pitch cankers. While masses of this fungus occur on the roots of diseased trees, no killing of tissue has been observed under them.

Healthy young roots were inoculated with the *Torula* and with *Poria cocos* through slits in the bark. Both produced extensive killing of the bark, resembling brown patch, often with much pitch exudation. To determine what these fungi would do to fine roots, the root systems of 2- and 3-year-old shortleaf pine seedlings grown in pots were inoculated by placing near the roots a spoonful of wheat with the fungus growing on it. Within 3 months the *Poria* had killed all but a few trees, and within 6 months the *Torula* did likewise. The *Poria* was particularly voracious in its attack on the roots, and both fungi killed trees by destroying roots. These experiments demonstrate that under certain conditions both of these fungi, which are widely distributed in our native soils, are capable of destroying the fine root systems of young shortleaf pines. The next question was whether these fungi, grown in quantity and placed against a large part of the root systems of trees of at least pole size, would kill enough roots to produce little leaf symptoms. These large-scale inoculations have been made, but as only one growing season has elapsed, the results have not yet had an opportunity to develop.

The mycorhizae do not differ sufficiently in type, condition, or abundance between diseased and healthy trees to account for little leaf. All mycorhizae were richly branched and ectotrophic, and very few pseudomycorhizae were found.

VIRUSES

There is a possibility that the little leaf disease may be caused by a virus. Several virus diseases of woody plants are known in this country, examples of which are the phony peach, the brooming disease of black locust, elm phloem necrosis, and elm mosaic, but no virus disease of a coniferous tree has yet been demonstrated. All known virus diseases of trees are transmissible by grafting or by transferring scions, root pieces, or bark patches from diseased to healthy trees.

During the spring of 1941 in Alabama and South Carolina small patches of living bark were lifted from the trunks and roots of little leaf trees and grafted into corresponding parts of 156 healthy trees more than 20 years old. Several such patch grafts were put on each tree. Some of the bark patches were so cut that some underlying wood was carried on them, and some included tissues only down through the cambium. In 1942 from 2 to 4 branches on each of 10 pole-sized healthy shortleaf pines were grafted with several bark patches from diseased trees. Although 4 growing seasons have elapsed since the first series of grafts was made and 3 since the branch grafts were made, there is as yet no clear evidence that the disease has been transmitted. An extensive grafting experiment has been set up, involving a great variety of grafting methods, in an attempt to explore further the possibility of so transmitting the disease.

To determine whether this disease is infectious, all diseased trees on a 1,000-acre national-forest tract in South Carolina are being harvested, and any that appear in the future will be cut promptly. This experimental eradication is to determine whether the future incidence of the disease will be reduced if all affected trees are removed soon after they can be identified and to develop information not only on its control but also on its infectiousness.

INSECTS

A continuous search has been in progress, in cooperation with the Division of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, for evidence of any connection of little leaf with the large number of insects that inhabit the southern pines. Thus far, there has been no evidence that little leaf is caused by insects. Investigation is being made, however, of a recent widespread infestation of shortleaf and associated pines by an aphid that feeds on the shoots. Bark beetles play a part in the death of some little leaf trees. Trees severely weakened by the disease and obviously very sickly may remain free from bark beetles until they die, but many in this condition attract and are quickly killed by *Ips* bark beetles. Turpentine beetles also have been found in little leaf trees. There is evidence that little leaf will occasionally result in *Ips* beetles breeding to the point of local epidemics, but there is little indication that the incidence of the southern pine beetle is affected by the disease.

PRESENT STATUS OF RESEARCH ON THE CAUSE

A general review of the research on the cause of little leaf permits the tentative elimination of some factors and focuses attention on others. The following seem not to be direct causes of the disease: Weather, lack of soil moisture, and deficiency of phosphorus or potassium. Factors that remain to be considered include certain other soil elements, the physical condition of the soil, two root fungi, other factors affecting the lateral root system, and the possibility that some virus causes the disease. The possibility also remains that little leaf is in some way related to changes in the characteristics of the surface soil resulting from some combination of factors involved in the change from predominantly hardwood in the virgin state to predominantly pine at the present time, or from repeated fires, erosion, and other land abuse, particularly on clayey soils.

CUTTING PRACTICES FOR AFFECTED STANDS

Whenever shortleaf or loblolly pine stands unexplainably begin to decline at an early age, and growth is very weak and foliage short and off-color, little leaf should be suspected, particularly if this occurs within the little leaf belt, as shown in figure 1. Single trees may show similar symptoms from other causes, but if little leaf occurs, large numbers of trees will usually be affected (fig. 5). Questionable cases should be referred to State or extension foresters or pathologists, or to the Division of Forest Pathology, Plant Industry Station, United States Department of Agriculture, Beltsville, Md.

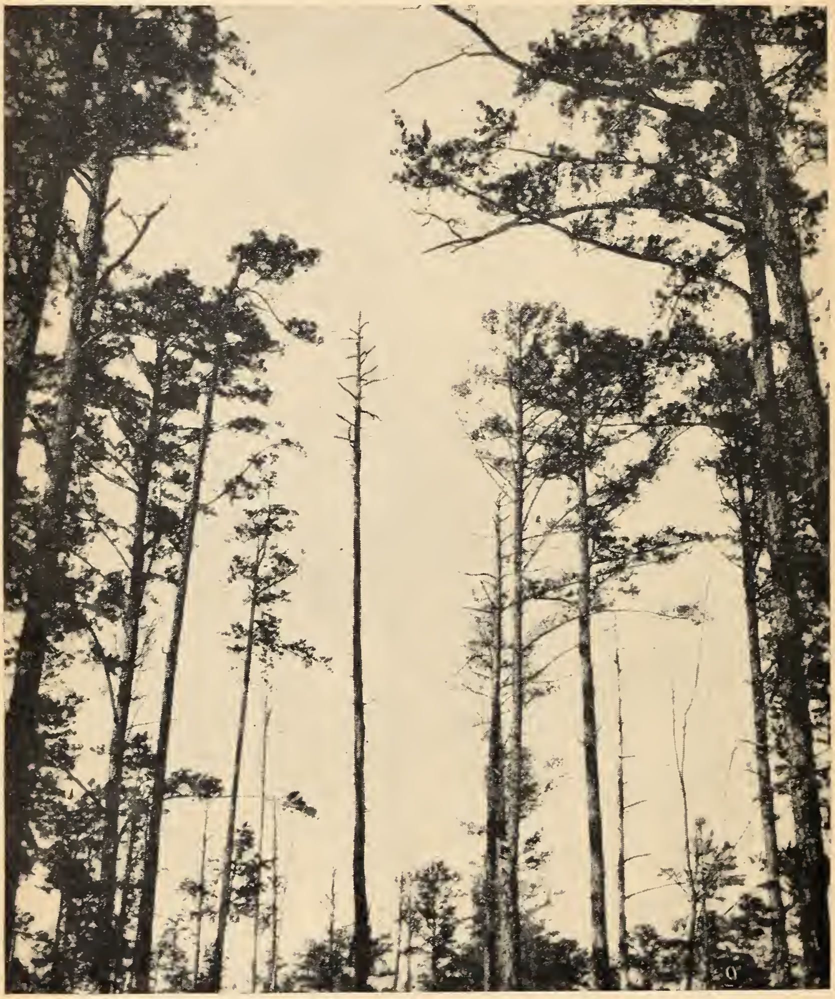

FIGURE 5.—A 50-year-old stand of shortleaf pine on a good site that is breaking up as a result of little leaf.

If the presence of little leaf is confirmed, plans should be made to harvest as much of the affected timber as possible. Since symptoms rarely appear until the trees are 20 years old or more, most diseased trees will at least produce pulpwood. Trees in the earliest recognizable stage of little leaf can be expected to live an average of 7 years, those in the middle stages 4½ years, while trees in advanced little leaf can be expected to survive only 2½ years. There is no evidence that the disease in any way impairs the usefulness of the wood if the tree is cut before it dies.

Particularly good opportunities for the salvage and marketing of affected timber are offered at a time when there is a critical shortage of pine pulpwood and the demand for lumber and cross ties is at a peak. As little leaf trees always die within a few years, prompt cutting will save them from early death and decay in the woods. The harvested wood will also bring a higher price than has prevailed in many years and will help alleviate the shortage of pine pulpwood needed by the southern pulp mills, which are turning out packaging materials not only for domestic use but also for food, supplies, and ammunition for the armed forces.

Two facts about the behavior of little leaf are especially useful in guiding the management of diseased stands: (1) Stands attain an age of 30 to 50 years before beginning to break up from little leaf; and (2) about 7 years elapse between the first evidence of crown symptoms and death. Mortality from little leaf is generally not excessive before trees are 35 years of age, but where the disease has appeared in abundance it is inadvisable to plan on a rotation age to exceed 50 years. Partial cuts should be made as often as volumes of diseased timber are available in operable quantities; in well-stocked severely affected areas this may be every 5 years. It should not exceed 7 years in a little leaf stand unless the cost of cutting small volumes of diseased trees is excessive. These practices will often result in the complete removal of the original stand at an age of not much more than 50 years.

The system of management here discussed obviously requires a market for trees of less than sawlog size. Within the past few years a great quantity of little leaf timber has gone into pulp, fuel, cross ties, and poles. Wherever a ready market for relatively small trees is not known to the timber owner, the State or extension foresters should be consulted. Wood, particularly pine pulpwood, is urgently needed, and the meeting of part of this need at a profit, with trees that would otherwise die and rot on the stump, should be investigated by all landowners whose timber is affected by little leaf.

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